Section 601. PCC PAVEMENT MIXTURES

601.01 Description. Concrete will consist of a mixture of Portland cement, blended Portland cement, cement substitutes, fine aggregate, coarse aggregate, water, and admixtures when required or permitted, combined in proportions for the various grades of concrete required.

“Sack" means a 94 pound sack of cement.

601.02 Materials. Materials shall meet the following requirements.

Provide air-entrained concrete unless otherwise specified.

Table 601-2 specifies the coarse aggregate required for the grade of concrete.

Ground granulated blast-furnace slag (GGBFS) may be used as an optional portion of the cementing material with Type IA or Type I Portland cement.

601.03 Construction. Furnish and maintain in reliable working condition, sufficient quantities of the equipment listed here, properly sized to maintain the progress schedule.

A. **NRMCA Certified Batching Plants.** Supply Portland cement concrete from certified portable and stationary concrete batch plant facilities meeting the requirements of the National Ready Mixed Concrete Association (NRMCA) certification program for automatic control and automatic systems including the following:

1. **NRMCA Plant Certification.**

a. **Stationary Concrete Batch Plants.** The Contractor/Concrete Producer will be responsible for the working order of plant equipment, facilities, associated weighing and batching devices, scheduling of inspections, and maintaining valid plant certification. Take action necessary to meet the requirements set forth in the NRMCA *Certification of Ready Mixed Concrete Production Facilities Quality Control Manual*.

Provide for scale inspection conforming to item 2.1.2 of the NRMCA *Quality Control Manual* - Section 3, "Plant Certification Check List" (herein after referred to as the NRMCA checklist) at intervals not exceeding six months.

Check the batching accuracy of all volumetric admixture dispensers and all volumetric water batching devices (including water meters) at intervals not

exceeding 90 days for conformance with items 2.5.3 and 2.5.4 of the NRMCA checklist.

b. **Portable Concrete Batch Plants.** Meet all requirements of subsection 601.03.A.1.a on an annual basis at start of production. After each move, verify by inspection, following the NRMCA checklist, that the plant meets requirements for certification and provide documentation of this inspection to the Engineer. A certified scale company must certify scales after each move.

Clearly display at each plant facility current inspection reports certifying that scales and volumetric batching devices are within tolerance. Conduct inspections with qualified company personnel, outside agencies or scale companies. Clearly display at each plant facility a photocopy of the NRMCA checklist, completed by the inspecting engineer, before providing material to the project. Clearly display at each plant facility the Certificate of Conformance, when it becomes available from NRMCA. Send current copies of the Certificate of Conformance, scale inspection reports and inspection reports on volumetric batching devices to the MDOT materials staff in the region in which the project is located. Failure to conform to these requirements must be corrected before continuing concreting operations.

The Department retains the right to inspect all batching equipment, facilities, and associated weighing and batching devices, and to review the qualifications of private plant and scale inspectors, or inspection agencies.

2. **Batch Tolerances.** Provide batching equipment capable of meeting the tolerances set forth in the NRMCA checklist as follows:

   a. **Cementitious Materials.** Within ±1 percent of the desired weight, or ±0.3 percent of the scale capacity for small loads (which governs for weights below 30 percent of the scale capacity).

   b. **Aggregates.** Within ±2 percent of the desired weights, or ±1 percent of the desired intermediate and final cumulative weights in aggregate batchers, or ±0.2 percent of the scale capacity (which governs for weights below 15 percent and 30 percent of the scale capacity for intermediate and final cumulative weights, respectively).

   c. **Water.** Within ±1.5 percent of the desired amount, or ±1.0 gallon, whichever is greater.

   d. **Admixtures.** Within ±3 percent of the desired amount or ± the minimum dosage rate per sack of cement, whichever is greater.

3. **Capacity.** Provide weighing and batching equipment with sufficient capacity to weigh, in a single weighing, the amount of each material required to complete the final batch unless the plant is equipped to weigh the materials by one of the following alternate methods.

   a. A device that will automatically cycle to provide the required number of increments

b. An automatic recording device that will provide a permanent record of the quantity of cement, aggregate, and water measured in each individual batch

4. **Ticketing System and Weekly Summary.** These requirements apply to truck mixed concrete and batch plant concrete. Provide a ticketing system which conforms to the provisions in Section 4, Ticketing System, of the NRMCA checklist. All information on the delivery ticket must be computer generated with the exception of the customer information which may be hand printed on each ticket.

   Provide a space on each ticket for the inspector to sign at the project site. When producing concrete for more than one project, include on each ticket a certification executed by the concrete producer stating that all materials used in the concrete have either been tested and approved, or certified as meeting the Department's specifications. When using a dedicated batch plant for only one paving project the delivery ticket does not require signature by the Inspector or a concrete producer certification .

   Provide an automated printout of target and actual batch weights with each delivery ticket. If this information is computer generated on a separate document, include on this document the serial number of the corresponding delivery ticket, or other means of cross reference. Securely attach the automated printout of target and actual batch weights to its corresponding delivery ticket. Collect tickets accompanying loads of concrete and give them to the Inspector.

   As necessary for proper control of the work, the Engineer may require additional information and a signature on the tickets.

   Provide a weekly summary of all daily batching operations with all shipments identified by project to the appropriate MDOT region materials staff.

B. **Non-NRMCA Certified Batching Plants.** Provide automatic cement and aggregate batchers.

1. **Weighing and Batching Equipment.** Provide weighing and batching equipment with capacity sufficient to weigh, in a single weighing, the amount of each material required to produce properly proportioned concrete unless the plant is equipped to weigh the materials by one of the following methods.

   a. A device that will automatically cycle to provide the required number of increments for a batch.

   b. An approved automatic recording device that will show the number of increments placed in each batch.

   With either method, the batch increments will be of equal size, unless the weighing equipment is capable of automatically meeting subsection 601.03.A for varying batch sizes.

Weigh cement and aggregates on separate scales in separate weigh hoppers, except for plants specially equipped to weigh cement cumulatively with aggregates, by first weighing cement into an enclosed compartment of a single weigh hopper. If cement is weighed cumulatively with aggregates, the batching tolerances will be as specified in subsection 601.03.A.2. The discharge of cement and aggregate will comply with subsection 601.03.A except discharge cement to within one percent of the batch weight of cement. Discharge aggregates to within one percent of the combined batch weights of the aggregate or 94 pounds whichever is less.

When fly ash or ground granulated blast-furnace slag is used as a blending material, it may be weighed cumulatively or separately with the Portland cement.

2. **Bins and Hoppers.** Provide the following.

   a. Equipment to load aggregate bins that can transport and discharge the aggregate into the bins without spillage into other stockpiles, bins, or compartments.

   b. Weathertight bins for cement, fly ash, and ground granulated blast-furnace slag.

   c. Weighing hoppers of suitable size and shape to hold the materials without leakage and supported entirely upon the scales.

   d. Hoppers and appurtenances designed and constructed to prevent loss of the materials by air currents or other means during weighing and discharge.

   e. Protection for the materials against loss or damage while transferring them from the weigh hopper to the mixer.

3. **Scales for Cement, Fly Ash, Ground Granulated Blast-Furnace Slag, and Aggregates.** Have at least 500 pounds of test weights meeting the requirements of NIST *Handbook 44* readily available for calibrating and testing weighing equipment. Provide such devices and assistance as required to enable the Engineer to check the accuracy of the scales.

   Use beam, springless dial, or digital type scales, or combinations of them, which comply with the requirements of NIST *Handbook 44* with the following exceptions and additions: Scales will be accurate within ±0.2 percent of the net load in the hopper, or one minimum graduation, whichever is larger. Unless the plant is equipped with a visual batch weight readout, equip the batcher scales with an electrical indicator device that will show by different colored lights when the net load on the scale is outside the tolerances specified under subsection 601.03.A.2. Each indicator light will be at least 40 watts or of intensity satisfactory to the Engineer.

   a. **Beam Scales.** Use beam scales with as many beams as the number of different kinds of material to be weighed on the scale. Provide beam scales with individual beams of adequate capacity to allow the required weight of each material to be set.

Equip each beam scale with an indicating device, such as a telltale dial, that will indicate to the scale operator that the weigh hopper is approaching the required load. This device will have one predominant mark showing balance. The over travel of such dials will be at least one-third of the loading travel. Telltale dials will show an overload on the scales.

b. **Dial Scales.** Provide graduated dials with suitable markers, unless waived by the Engineer, capable of being set to show the position of the dial indicator for predetermined loads.

4. **Automatic Controls.** Except for manually operated plants meeting subsection 601.03.C, provide automatic controls for batching equipment with individual starting mechanisms for each material or by a single starting mechanism for all materials that, when actuated, will control all functions of the weighing and metering operations for the materials. For each material weighed, the specified weight will be in the weigh hopper and the scale indicator at balance within the specified tolerance limits for at least one second before the succeeding operations can continue.

   Equip the automatic control for each batching scale system with a device for stopping the automatic cycle in both the underweight and overweight check positions for each material so that the tolerance setting may be checked.

   Electrically operate and automatically interlock automatic batchers so that for each material being weighed, the following controls will be in effect:

   a. Interlock the hopper inlet mechanism against opening when the discharge gate is open.

   b. Interlock the hopper discharge mechanism against all of the following:

      i. Opening while filling the hopper

      ii. Opening until the full batch is in the hopper and the scale balanced

      iii. Opening if the batch in the hopper is either overweight or underweight by more than the specified tolerance

      iv. Closing and locking and a succeeding batch started until the hopper is emptied to the lessor of one percent of the batch weight for the scale, or 94 pounds.

   Do not allow the sensing mechanism for the automatic control system to exert a force on the scale weighing mechanism, or indicating mechanism, which affects the scale accuracy through any portion of the weighing range of the indicator.

   Equip each dial scale system with a removable dial puller which inspectors can attach to the dial lever system so that they can move the dial smoothly and slowly through its range to check the settings of the automatic control system.

Provide all weighing systems equipped with load cells with a device capable of simulating load conditions to enable verification of proportioning setpoints and interlocking tolerances for each material. Equip the device with the ranges or adjustments necessary to enable each consecutive value of digital indication to be displayed and held for a time interval required to perform the inspection.

The plant operator will complete the automatic control system checkout procedure periodically as requested by the Engineer.

5. **Dispensers and Controls for Liquid Admixtures.** Dispensers must measure the admixture volumetrically. Batching controls must be located and constructed that the operator can visual monitor accuracy of admixture delivery. Activate the admixture dispenser system by the single starting mechanism of the entire batching system or any of the primary ingredients of the mixture. Introduce the admixture into the sand, the water line, or directly into the mixing drum. Use a separate dispenser for each admixture.

   When more than one admixture is used, avoid intermixing of admixtures before introduction into the mixture by having the dispensers function as follows.

   a. Outlet into different portions of sand in the weigh hopper.

   b. Outlet into different locations in the water line.

   c. Outlet separately into the sand, the water line, and/or the mixer drum.

   d. Cycle through a common outlet to dispense only one admixture at a time.

   Provide a dispenser piping system free from leaks and properly valved to prevent backflow or siphoning.

   Provide the dispenser system for admixtures that can measure and dispense the quantity required for each batch. The dispensing system must include a device or devices that will either indicate the flow of admixture, or indicate whether admixture is present in the dispenser.

   The dispensing device must have an accuracy of ±3 percent of the required volume of material batched or ±1.0 fluid ounces, whichever is greater. Equip the plant with the necessary calibrated devices to check the dispensed volume to the required accuracy.

   The batching controls will start the batching operation and stop the flow automatically when the designated volume has been measured. They must visually indicate when the batching operation is complete.

   Interlock the admixture dispenser system with the batching operations. Interlock the dispenser so that it must reset to start before it may be charged. Interlock so that it cannot start discharge of the admixture unless the controls have been cleared of the previous batch with the volumetric devices resetting to start or signaling empty.

6. **Additional Requirements for Plants Using Non-Air-Entraining Cement.** Activate the dispenser system for the air-entraining admixture automatically by a batching signal from the control panel. A positive displacement meter will transmit pulses calibrated at fixed amounts of the admixture to an impulse counter connected to the panel. Interlock the impulse counter to prevent operations of the batching sequence from functioning if the prescribed quantity of the admixture is not recorded on the counter. In addition, discharge from the metering device into a transparent calibrated column, located so the plant operator can visibly check the flow and quantity of the admixture provides a secondary indication. When, in the determination of the Engineer, placing the calibrated column in view of the operator is not practical, install a signal readily visible to the operator, actuated by a sensor in the calibrated column to show the presence of the admixture in the calibrated column.

7. **Water Measuring Equipment.** Measure water either by volume or by weight. When required by the Engineer, demonstrate the accuracy of the water measuring equipment. The water system must discharge substantially all of the required water into the mixer drum before one-third of the specified mixing time has elapsed. It must cut off the flow automatically when it has discharged the designated amount of water. Provide an indicator to show the water used in each batch.

8. **Mixers.** Batch mixers must be of an approved design meeting the requirements specified herein. Mixers must combine the aggregates, cement, water, and admixtures and of discharging the mixture without segregation.

   Provide portable and central mixers of the batch type. Equip them with a timing device that will automatically lock the discharge mechanism during the full time of mixing and release it at the end of the mixing period. The mixer must be capable of mixing the entire volume of batched material in one operation.

   Truck mixers must be of the revolving drum type and be in good condition. None of the ingredients of the mix, including water, will be added or lost by leakage or spillage from the time of charging until discharged. Equip the mixer with an approved revolution counter. Use truck mixers that can be emptied of water collected in the mixer drum through washing.

   All mixers shall have a metal plate attached which includes the following information.

   a. Serial number

   b. Maximum mixing capacity in terms of volume of mixed concrete

   c. Mixing speed of the drum

   d. On truck mixers and agitators show the maximum agitating capacity in terms of volume of mixed concrete and the agitating speed of the drum or blades.

9. **Concrete Hauling Units.** Provide hauling units capable of delivering concrete in a nonsegregated condition. Equipment used for transporting concrete must be in good

condition. None of the mixture, including water, will be added or lost by leakage or spillage from the time of loading until discharge.

10. **Continuous Batching and Mixing.** Continuous batching and mixing equipment must meet the requirements of ASTM C 685.

11. **Inspector Facilities.** The Contractor will provide space for the inspector to continuously observe the batching operation.

    When water/cementitious ratio determinations are required, furnish sample-drying equipment and work and storage areas suitable for performing moisture tests and storing the equipment.

    Provide desk space in commercial plants, for the inspector's use.

C. **Waiver of NRMCA Certification and/or Automation Requirements.** If there is no fully automated, NRMCA certified facility within 25 miles of the project limits, the Engineer may waive NRMCA certification and/or automation requirements as follows.

1. **Waiver of Certification**. The Engineer may allow the use of non-NRMCA certified, automated plants only if there is no fully automated, NRMCA certified facility within 25 miles of the project. All requirements of subsection 601.03.B will still apply.

2. **Waiver of Automation and Certification.** The Engineer may allow the use of non-NRMCA certified, manual plants only if there is no automated plant with batching facilities as specified in subsection 601.03.B within 25 miles of the project. In this case the following devices specified by subsection 601.03.B are not required.

    a. Automatic incremental batch cycling devices

    b. Interlocking devices for cement and aggregate

    c. Electrical tolerance indicator devices

    d. Automatic dispensers for admixtures

Approved manual plants not having air-entraining cement may produce air-entrained concrete by using an air-entraining admixture and a Type I, IS, or IP cement according to the options permitted in Table 601-2.

D. **Furnishing and Handling Materials**

1. **Aggregates** Furnish, stockpile and handle the fine and coarse aggregates to prevent segregation. Place fine aggregates, coarse aggregates and aggregates secured from different sources in separate bins or stockpiles. Provide firm, level ground for stockpiles and thoroughly clean the area of all foreign materials. If stockpile areas are not paved, do not use the bottom 12 inches of the stockpile. Do not use frozen aggregate lumps. Do not use equipment that causes contamination or degradation.

Keep the aggregate moisture content uniform for each day's run without evidence of surplus water. Keep stockpiles of slag or other highly absorptive aggregates at a uniform moisture content by approved methods described in the Contractor's quality control plan.

Store fine and coarse aggregates for Department work in separate piles or bins apart from aggregates for other work. Stockpile each gradation separately when the coarse aggregate consists of a blend of two more gradations.

2. **Cement, Ground Granulated Blast-Furnace Slag, and Fly Ash.** Store cement, ground granulated blast-furnace slag, and fly ash furnished in bulk form in separate weatherproof bins. Do not use wet or contaminated material.

   Empty bins to less than the quantity used for two batches of concrete before refilling with new material if the source of cement or fly ash changes or if the source or grade of ground granulated blast-furnace slag change.

   Record the change of source or grade of cementitious material on the first ticket for concrete delivered to each project.

   Furnish the Engineer with a copy of the shipment notice showing the quantity of cement, ground granulated blast-furnace slag, or fly ash in each shipment and a certification that the material meets Department specifications.

E. **Mixing Concrete.**

1. **General**. Produce and deliver ready mixed concrete as either central or truck mixed concrete. Central mixed concrete is concrete completely mixed in a central mixer and transported to the delivery point in a truck agitator, a truck mixer, or in approved non-agitating equipment. Truck mixed concrete is concrete completely mixed at the plant site in a truck mixer with an approved revolution counter.

   The Contractor must provide communication service from the project site to the batching plant that will be available to the Engineer during concreting operations.

   The mixer drum must be completely emptied after each batch before recharging. The maximum batch size may not exceed the capacity of the mixer as shown on the attached metal plate. Batch sizes for agitating units and truck mixers used to transport central mixed concrete may not exceed the manufacturer's recommendation for maximum agitating capacity.

2. **Batch Mixing.** The mixer must operate at the speed or speed range recommended by the manufacturer and shown on a metal plate attached to the mixer.

   The mixing time is the elapsed time between charging of all cement and aggregates and the beginning of discharge of the concrete. For multicompartment mixers the mixing time includes the transfer time between drums. Charge the ingredients into the mixer so some of the water enters in advance of cement and aggregate and so that

substantially all the water is in the drum before one-third of the specified mixing time has elapsed.

a. **Central Mixed Concrete.** The minimum mixing time required for mixing each batch of central mixed concrete is 60 seconds or as described in the Contractor's quality control plan. For revolving drum mixers having a capacity of one cubic meter or less, the minimum mixing time is 90 seconds.

b. **Truck Mixed Concrete.** Mix each batch of truck mixed concrete for more than 70 revolutions at mixing speed.

3. **Elapsed Time.** Charging begins when the cement meets the mixing water or damp aggregates. The time between charging the mixer and the completion of discharging may not exceed that specified in Table 601-1.

   Continuously agitate the concrete when the time between charging and completion of discharge may exceed 30 minutes.

Table 601-1 Maximum Time Between Charging of Mixer and Placing of Concrete

Type of Unit	Concrete Temperature (ASTM C1064) °F		
	<60 °F	60 °F to 85 °F	>85 °F
Open Top Trucks	60	60	30
Open Top Agitating Units	60	45	30
Closed Top Agitating Units and Truck Mixers	90	60	45
Truck Mixers and Closed Top Agitating Units with Concrete Containing Water-Reducing Retarding Admixture	120	90	70

4. **Additional Water at Placement Site.** The maximum cumulative water added to the concrete mixture must not exceed the maximum water content and maximum water/cementitious material ratio specified for the approved concrete mix design. Document all water added after batching on the delivery ticket. Document the resulting water/cementitious material ratio and provide this information to the Engineer on a daily basis. For concrete transported in truck mixers, water may be added if additional mixing water is required to obtain the specified slump, and the truck mixer is not loaded over its rated mixing capacity. After all water is added, allow a minimum of 30 revolutions of the truck mixer drum at mixing speed before discharging any concrete. This additional water must be added and the additional mixing completed at the project site within the maximum time in subsection 601.03.E.3.

F. **Concrete Temperature Requirements.** Concrete must be at a temperature of 45 °F to 90 °F at the time of placement.

1. **Heating of Ingredients for Concrete.** Heat the ingredients for concrete whenever necessary to produce concrete having a temperature of at least 45 °F. Heat the water and/or aggregates. Do not heat aggregates to more than 150 °F. Mix the water with the heated aggregates before adding cement. When heating the concrete ingredients, the concrete temperature must not exceed 80 °F, and when placed in insulated forms the temperature must not exceed 70 °F.

   The aggregates must be free of ice and frozen lumps at time of batching. Use steam or hot water coils, live steam, or indirect hot air to heat aggregates in stockpiles or bins.

   Do not heat coarse aggregates by direct flame. Remove accumulated condensation from heating before batching operations to maintain slump within allowable limits.

2. **Concrete Accelerators.** When the mean daily air temperature is expected to remain below 45 °F during the curing period, the Engineer may allow or require the use of additional cement or an admixture to accelerate the rate of strength gain. Do not use a calcium chloride admixture unless the Engineer determines it is needed to meet maintaining traffic requirements. The concrete mixture requirements must be determined per subsection 601.03.G and must include the increased cement content or the admixture content.

   When the Engineer authorizes calcium chloride as an admixture, the calcium chloride may be added manually as a solution or in a lump-free flake or pellet form. Distribute the material uniformly to ensure that it does not come in direct contact with dry cement. Premixed liquid calcium chloride solutions delivered to the job must meet the requirements outlined in this section. Prepare job-mixed calcium chloride solutions in the presence of the Engineer.

   When the Engineer authorizes the use of a calcium chloride admixture and the air temperature in the shade and away from artificial heat is between 40 °F and 45 °F, add calcium chloride at the following rates for each 94 pounds of cement in the batch. For air temperatures below 40 °F, the Engineer may require that the quantity of admixture be increased to a maximum of twice the following rates.

77 percent grade calcium chloride:	1.0 pound
94 percent grade calcium chloride:	0.8 pound
Job-mixed solution:	1 quart (32 fluid ounces)*
Premixed Solution:	1/5 gallon (25.6 fluid ounces)*

   *Note: Each quart of solution must contain 1 pound of 77 percent grade, or 0.8 pound of 94 percent grade, calcium chloride.

G. **Concrete Mixture Requirements.**

1. **Contractor Mix Designs.** All projects which include 100 cubic yards or more of a single grade of concrete will be subject to the provisions of the Department's concrete quality assurance programs. Mix designs for these projects are the responsibility of the Contractor and must meet the requirements of section 605.

2. **MDOT Mix Designs.** The Engineer must provide the mix design requirements on projects not covered by the Department's concrete quality assurance program. These mix designs will be based on the Contractor's choice of materials from approved sources.

   Mix designs will designate the amount of cementitious materials, fine aggregate, coarse aggregate, and water required per cubic yard of concrete. Restrict modifications to a Department provided mix design to increased cement content, increased coarse aggregate content, or decreased water content, at no cost to the Department.

3. **Mixes Using Additional Fly Ash or Ground Granulated Blast-Furnace Slag.** Fly ash may be used in the concrete mixture according to Table 601-2. A greater quantity of fly ash or ground granulated blast-furnace slag (GGBFS) may be used, subject to the following requirements.

   a. Submit a mix design produced by a testing laboratory conforming to ASTM C 1077 for review by the Engineer. Include documentation of the 28-day compressive strength, slump and air content. Show that the concrete produces a 28-day compressive strength at least 500 psi higher than the requirements in Table 601-2. Make, cure and test a minimum of three batches of each mix design according to ASTM C 192. Provide new laboratory data for reapproval by the Engineer for all subsequent changes in any of the mixture constituents.

   b. Use Type I or IA Portland cement.

   c. Reduce the cement quantity shown in Table 601-2 up to a maximum of 25 percent for fly ash substitution or up to 40 percent for GGBFS substitution.

   d. The fly ash or GGBFS weight additions must be equal to 1.0 times the weight of the cement reduction.

   e. For concrete containing Portland cement, fly ash and GGBFS in the same mix design, reduce the cement quantity shown in Table 601-2 up to 40 percent, with the maximum fly ash quantity not exceeding 15 percent.

3. **Air Content.** Do not use air-detraining admixtures. At the time of placement, concrete must have 6.5 ±1.5 percent entrained air, except that for concrete furnished for placement by slipform methods and having a slump of 1.5 inches or less, the minimum entrained air content must be 4.5 percent.

   Determine the air content of freshly mixed concrete by the Department's modification of ASTM C 231 Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method, or by ASTM C 173 Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method. Take samples by Department methods.

   Determine the air content of freshly mixed concrete containing slag or other highly absorptive coarse aggregate by the volumetric method, ASTM C 173. Take samples by Department methods.

Adjust the air-entraining admixture used per batch to provide the specified air content in the concrete. Select air-entraining admixtures from the Qualified Products List. When adjusting the air-entraining admixture, record the amount used per sack of cement or per batch of concrete on the first delivery ticket following the adjustment.

When concrete in truck mixers is found to have low air content at the project site, add additional air-entraining admixture as necessary and ensure proper mixing. Notify the concrete plant to make appropriate adjustments before batching additional loads.

4. **Water-Reducing Admixtures.** Concrete mixtures containing an admixture must meet the same strength, slump, and air content requirements as the respective grade of concrete without an admixture.

   Select water-reducing admixtures from the Qualified Products List. When an admixture is used, use not less than the dosage shown on the Qualified Products List. Admixture dosage rates are based on the total cementitious material (cement plus fly ash or ground granulated blast-furnace slag) in the concrete.

5. **Slump.** Determine the slump of fresh concrete by ASTM C 143 the slump cone test, except take samples by Department methods at the project site. Do not exceed a slump of 3.0 inches or the slump indicated in the Contractor's approved mix design.

6. **Strength of Concrete.**

   a. **Concrete QA Projects.** Strength of concrete for acceptance and payment will be determined according to section 605 for all projects covered by the Department's concrete quality assurance program.

   b. **Non Concrete QA Projects.** Make two representative concrete test specimens from the concrete being incorporated in the work. Furnish concrete for test specimens and labor for making and transporting them without charge. The Department will furnish molds and testing equipment for specimens. Flexural strength will be used for opening to traffic and compressive strength for acceptance in all other paving situations.

   Make test specimens according to Department procedures, which are based on AASHTO T 23 Method of Making and Curing Concrete Compressive and Flexural Strength Test Specimens in the Field. Cure test specimens according to AASHTO T23 Section 9.2, Curing Specimens as Basis of Acceptance Using Standard Curing, or Section 9.3, Curing Specimens as Basis of Acceptance at Remote Sites Using Modified Standard Curing.

Table 601-2 Concrete Pavement Mixtures

Cement Type is shown in Col. 2 (1) = I-A (2) = IS-A, (SM)-A (3) = IP-A, (PM)-A				Minimum Class Design Strength (a)							
				Flexural strength, psi (at 3, 7, 14 and 28 days)				Compressive Strength, psi (at 3, 7, 14 and 28 days)			
Grade of Concrete (b) (c)	Cement Content (d) (e)		Fly Ash lb/cyd	3 days	7 days	14 days	28 days	3 days	7 days	14 days	28 days
	lb/cyd	sacks									
HE (f)	658 (1) (2)	7.0	0	550	600		650	2610	3045		3500
	790 (3)	8.4	0								
P1	564 (1) (2) (3)	6.0	0		550	600	650		2600	3000	3500
	526 (g) (1) (2) (3)	5.6	0								
	517 (1)	5.5	78								
	480 (g) (1)	5.1	72								
P2	517 (1) (2) (3)	5.5	0		500	550	600		2200	2600	3000
	489 (g) (1) (2) (3)	5.2	0								
	470 (1)	5.0	71								
	451 (g) (1)	4.8	68								
M	Commercial grade concrete containing 517 pounds (5.5 sacks) of cement per cubic yard. Portland cement may be reduced up to 20 percent, by weight, when 1.0 pound of fly ash is substituted for each pound of cement removed.										
X	Unless otherwise specified, Grade X concrete contains a minimum of 282 pounds (3.0 sacks) of cement per cubic yard. Portland cement may be reduced up to 20 percent, by weight, when 1.0 pound of fly ash is substituted for each pound of cement removed.										

a. Use flexural strength for opening to traffic and compressive strength for acceptance in all other paving situations.
b. Use coarse aggregate 6A, 6AA or 6AAA for Grades HE, P1, P2 and M. Use coarse aggregate 6AAA for all mainline concrete pavement and ramps unless the directional commercial ADT is less than 250 vehicles per day.
c. The mix design basis for bulk volume (dry, loose) of coarse aggregate per unit volume of concrete is 72% for Grades HE and P1; and 74% for Grade P2.
d. Do not use concrete mixtures containing type IS-A, I(SM)-A, IP-A, or I(PM)-A cement or containing ground blast-furnace slag or fly ash, on projects in the Lower Peninsula between October 15 and April 1, nor in the Upper Peninsula between October 1 and April 15 unless otherwise detailed in the Contractor's approved mix design in the approved Quality Control plan.
e. May use non-air-entraining cement corresponding to the types of air-entraining cement listed with an approved air-entraining admixture to produce the specified air content.
f. Refer to 603.02A when Grade HE is used.
g. Use the quantity of Type A water- reducing admixture indicated in the Qualified Products List to provide reduction in mixing water and is required for mixes having reduced cement content.

Flexural strength must be determined according to Department procedures that are based on a modification of ASTM C 293 Test Method for Flexural Strength of Concrete (Using Simple Beams with Center-Point Loading). Compressive strength of test specimens must be determined according to ASTM C 39. If compressive strength is determined on beam ends according to ASTM C 116, the strength value will be reduced by a correction factor of 20 percent.

If the average compressive strength of two companion cylinders or the flexure strength of the beams is less than the 28-day strength specified by Table 601-2, then the Engineer may take action as described in subsection 601.04.

H. **Work Progress Specimens.** The strength of concrete for opening to vehicular traffic will be the 7-day flexural requirement of Table 601-2. Refer to subsection 104.11 for requirement for opening to construction traffic. Make and cure a series of test cylinders or beams under the same environmental conditions as the pavement. The Department will test all specimens for open to traffic strength determination.

601.04. Measurement and Payment. Payment for PCC pavement mixtures, associated materials, equipment, and labor is included in other contract items (pay items).

For concrete not covered by section 605, the Engineer may require the following corrective action or pay adjustments based on compressive or flexural strength of concrete.

A. Require the Contractor to remove and replace the concrete pavement at no cost to the Department.

B. Determine if the concrete has sufficient structural strength; if so, adjust the unit price for affected pay items and quantity represented based on the following formula:

$$\text{Adjusted Unit Price} = \frac{\text{Tested Strength}}{\text{Class Design Strength*}} \times (\text{Unit Price})$$

* Compressive or flexural strength as shown in Table 601-2.

C. Allow the Contractor to submit a plan, for approval by the Engineer for corrective action at no cost to the Department. If the plan for corrective action is not approved, A or B may be applied.

D. Re-evaluate the material by obtaining 6 cores for compressive strength testing. Based on the core test results, the Engineer may apply A, B, or C above.